THE WEAPON OF PEACE

As Nigel Cook reports, four out of five ideas of Winston Churchill on the future of war, published in 1925, have become reality. And the fifth? Read on...

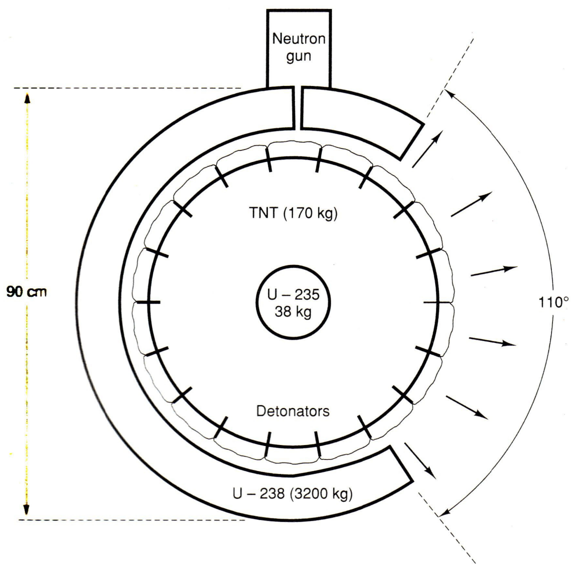

Fig. 1. Vertical cross section through the directed EMP weapon. Prompt gamma rays are radiated horizontally from a circular aperture to maximise the net (asymmetrical) Compton current parallel to the ground. The bomb weighs 3.4 metric tons and is 90cm across. (The bomb dropped on Hiroshima was 3m long and has a mass of 4.1 metric tons)

In an article published in 1925, Winston Churchill posed five ideas on the future of war. The first four have all become reality. The first is nuclear weapons; "Might not a bomb no bigger than an orange be found to possess a secret power – nay, to concentrate the force of a thousand tons of cordite and blast a township at a stroke?" Next is guided missiles and rockets; "Could not explosives even of the existing type be guided automatically in flying machines by wireless or other rays, without a human pilot, in ceaseless procession upon a hostile city?" Thirdly, poison gas and chemical warfare; "only the first chapter has been written in this terrible book." And finally, biological warfare; "Blight to destroy crops, Anthrax to slay horses and cattle, plague to poison not armies but whole districts".

The US Department of Defense has just undertaken the development of the fifth and final suggestion. Churchill's article entitled *Shall We All Commit Suicide?*, offered as the last word on the technology of war a suggestion which previously seemed pseudo-scientific fantasy. But, just like his other ideas, science has finally caught up. Churchill's fifth idea; "It might have been hoped that the electromagnetic waves would in certain scales [frequencies] be found capable of detonating explosives of all kinds from a great distance."

A need has recently arisen for a new weapon which could stop nuclear reactor plutonium production in threatening countries seeking nuclear weapons. According to Pentagon sources, it could also be used to effectively halt conventional warfare without killing or injuring anyone (by destroying the electronic components of weapons), or, indeed, actually detonate all the explosives as Churchill imaginatively suggested 69 years ago. Nuclear reactors cannot be attacked with conventional explosive weapons without the risk of releasing radioactivity which could injure civilians.

Harold Smith, assistant to US defence secretary Les Asin, summarised the requirements in December 1993: "We need a weapon today that will bring a reactor to a standstill, that would not contaminate the surrounding atmosphere." Ashton Carter, assistant US secretary of defence in charge of counter-proliferation, added during the same interview: "We're talking about a new mission." To accomplish this, they have authorised the development of a new bomb which releases an electromagnetic pulse powerful enough to destroy all electronic equipment targeted, without producing early fallout.

The EMP weapon is not an essentially secret invention and can therefore be discussed here in some detail. Like the neutron bomb, the weapon itself is a very fundamental concept to nuclear design, and the special features pertain only to the yield, height of burst, and an outer radiation shield. To optimise the EMP, the fraction of the bomb's total yield which appears in prompt gamma rays must be maximised. Prompt gamma rays are the only source of gamma radiation emitted at a high enough rate (or power) to create a charge separation in the atmosphere sufficient to produce a damaging EMP. About 3.5% of the energy of nuclear fission is released in this form. The shorter the interval of time over which the fission reaction occurs, the greater the rate of prompt gamma emission, the larger the electric field, and the greater the frequency of EMP. Research recently declassified shows that the tamper of a low yield fission bomb absorbs over 85% of the prompt gamma rays.

To meet these objectives the EMP weapon deploys a pure fission implosion bomb with no heavy uranium tamper. This is conventionally used to reflect neutrons back into the fission reaction and to protract the explosion process by inertia, thereby increasing the per-

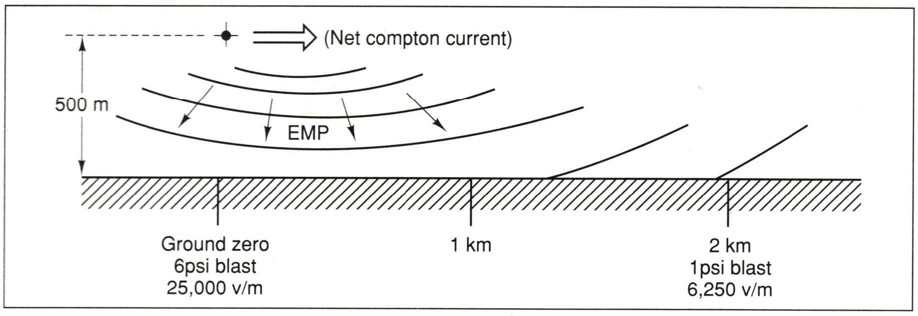

Fig. 2. Directed EMP weapon is used operationally like the neutron bomb. However, the EMP weapon minimises the dangerous effects to people and maximises the high-power microwave (100MHz) electromagnetic pulse emission. This couples immense currents in cables, aerials and power lines which rise faster than lightning and burn out electromagnetic components.

centage of mass fissioned and with it the total yield. The absence of a tamper therefore lets the core expand and the reaction be quenched after only a kiloton of TNT equivalent energy has been generated.

The resulting one kiloton burst at 500m altitude is identical to the neutron bomb; in that the blast, fallout and thermal effects are virtually negligible on the ground. The difference is that the neutron bomb is a complex thermonuclear devise to maximise the neutron radiation yield; the EMP weapon is basically a simple pure fission device maximising the relative yield of prompt gamma rays.

For the purpose of countering nuclear reactors, it is anticipated that EMP bombs will use highly enriched uranium-235 rather than plutonium, since it is too expensive for making a great stockpile of bombs and is many thousands of times safer than plutonium. In fact, the concentration of U-235 needed to cause a radiation injury when ingested is more important for chemical poisoning to the kidneys.

With the source of gamma radiation known, the problem is then using it to produce a directed EMP. The principle is simple: the prompt gamma rays are scattered on average every 300m in the air surrounding the bomb. The scattering mechanism is the Compton effect, whereby an electron in the air is ejected from its atom, leaving the latter ionised.

Since the electron has a far smaller inertia than the ion, it travels outward faster. This separation of charges creates an electric field which, according to Maxwell's equations, is greatest perpendicular to the direction of the so-called 'Compton current'. An ordinary nuclear explosion in the air produces an EMP due to the variation of the air density with altitude, because a vertical asymmetry in the otherwise spherical Compton current is produced. An asymmetry in the radial current is essential for EMP or any radio emission: a radio aerial can be almost any shape except a sphere.

The problem with the natural vertical EMP (which has been understood since the 1960s) is that, if the weapon is air burst (to avoid fallout), the minimum fields occur directly below the detonation, and the maximum fields occur at a long distance in a circular region around ground zero. This effect again occurs in radio transmission: the minimum reception occurs directly above or below a vertical aerial, while the maximum fields are radiated horizontally.

The EMP weapon creates an artificial horizontal asymmetry in the Compton current by absorbing the gamma radiation travelling upwards and downwards from the bomb in a natural outer shield. The prompt gamma rays are all emitted within 10ns (for a one kiloton bomb), which is well before the bomb has destroyed the shield by heat and hydrodynamics. The idea of introducing such artificial asymmetry into nuclear weapons was first put into practice in the successful Ming Blade underground nuclear test at the Nevada Test Site in 1974. This was done to confirm the theoretical model used for surface burst nuclear weapon EMP, so that cold war missile silo equipment could be protected. Of greater interest today are the data from Dining Car, a 1975 nuclear test at Nevada where military hardware was for the first time deliberately subjected to an EMP from a real nuclear explosion. Since the end of the cold war, the Defense Nuclear Agency in America has classified the results of such tests, and even its secret manual entitled *Capabilities of Nuclear Weapons*.

19 June 1974

5 April 1975

The design of the EMP weapon is shown in **Figs. 1** and **2**. It is a simple and yet highly controllable invention. The heavy radiation shield, while maximising the radiation flash environment high in the air, absorbs most of the downward directed radiations and thus avoids producing casualties on the ground. The exact variation of EMP around ground zero is precisely determined by the solid angle through which radiation is allowed to escape from the bomb, and by height of burst. As the emission angle is increased, a greater amount of prompt gamma radiation escapes. However the symmetry of the radiation field also increases with the emission angle, which means that a smaller fraction of the gamma radiation is then radiated as EMP. On balance, the optimum angle is 110°, for which about one sixth of the prompt gamma radiation is emitted into the air.

Burst at an altitude of 500m to avoid early radioactive fallout and to achieve a merged and uniform EMP on the surface below, this bomb would blanket a square kilometre with a peak EMP of 25kV/m. At greater distances, e.g., outside the radius of radiation absorption high in the air, the field decays inversely with distance. Therefore, the EMP falls to 6.25V/m at 2km ground radius, and to 2kV/m at 6km.

Experience in 1962 on Hawaii, 1,300km from the 1.4 megaton Starfish Prime nuclear test (detonated over Johnston Island), showed that an EMP of just a few kV/m can cause marked effects even on old electronic systems. For example, 300 street lights were fused in 30 series connected loops, dozens of burglar alarms were set off, and circuit breakers initiated power cuts in different circuits. Except for fuses, electronic equipment was not permanently affected since it takes about 1 to 2J to burn out a valve. However, microelectronics are a crucial component of nuclear reactors and modern weaponry, and they are thousands to millions of times more vulnerable than valve technology. For example, an MC17 silicon chip (data input gate) is burned out, according to the previously secret *Capabilities of Nuclear Weapons*, by an EMP of just 0.08mJ. Furthermore, promising to fulfil Churchill's prediction exactly, we find that various kinds of explosive detonators are fired off by an EMP of between 0.02 and 0.6mJ.

These effects would readily occur out to a distance of between 2 and 6km from ground zero. For comparison, serious skin burns, caused for a one kiloton bomb by a thermal exposure of $5cal/cm^2$, occur only to a ground radius of 500m; and the blast wave effect even at ground zero, where the peak overpressure would be 40kPa or $6lb/in^2$, would not be sufficient to structurally damage concrete buildings (for instance a nuclear reactor), owing to the very short duration of the blast from a one kiloton bomb. The Pentagon will therefore soon have at its disposal the first true weapon of peace. ■

References

1. Winston Churchill's 1925 article is reprinted in his book *Thoughts and Adventures* (Butterworth, 1932).
2. Assistants to US Secretary of Defense are quoted on the EMP bomb project in various American newspaper reports, e.g., Steve Komarow, *Technology: Pentagon's Driving Force, USA Today*, International Edition, Tuesday 28 December 1993.
3. Secret Pentagon manual recently released under the US Freedom of Information Act: Philip J. Dolan (ed.), *Capabilities of Nuclear Weapons*, Defense Nuclear Agency of the US Department of Defense, 1972. Revised 1978 and 1981.
4. The declassified figure of "over 85%" in the text of the article is based on Chapters 1 and 7 of *Capabilities of Nuclear Weapons*. These state that although thermonuclear weapons release only 0.1% of their total energy as prompt gamma rays, small fission bombs of one kiloton release 0.5%. Since the book states that 3.5% of the total energy of the explosion is in prompt gamma rays, the tamper obviously absorbs the other 3%, which is 85.7% of the total.
5. References to the nuclear test EMP are from Chapter XI of Samuel Glasstone and Philip J Dolan, *The Effects of Nuclear Weapons*, US Departments of Energy and Defense, 3rd ed., 1977.